



Technical Issues and Costs of Otolith Marking Prince William Sound Hatchery Pink Salmon

Harold J. Geiger

Kristen Munk

Brian G. Bue

Mark Willette

March 1994

TABLE OF CONTENTS

	<u>Page</u>
EXECUTIVE SUMMARY	1
INTRODUCTION	3
MARK APPLICATION	4
Physical Changes to the Hatchery	4
Gas Saturation	5
Mark Control	6
Specific Mark Assignment	6
MARK DECODING AND DATA POSTING	7
Quality Control	9
ESTIMATORS AND SAMPLING STRATEGY	10
Sampling Strategy	10
Sampling Mechanics	11
Sample Size	12
LITERATURE CITED	13
APPENDIX	14
Appendix Table 1. Schedule of activities and estimated costs	15
Appendix Table 2. Committee members	17

EXECUTIVE SUMMARY

Management -- whether management of people, manufacturing processes, or natural resources -- requires information about the consequences and effectiveness of management actions. The actual process of management is the collecting and processing of information, then taking control actions based on the information. Salmon managers need information on the temporal and spatial distribution of salmon stocks as well as catch contributions in mixed stock salmon fisheries. This information is particularly important in Prince William Sound where the size of the hatchery run can range from nearly equal to an order of magnitude larger than the wild run. This disparity in run magnitudes places wild salmon in jeopardy of overexploitation. Indeed, the wild runs have been overexploited in recent years as management has struggled to keep up with this ever more complex fishery. This is a plan for acquiring the information that salmon managers need in Prince William Sound -- information needed to extract the benefits from the hatchery and wild salmon resource, and still protect the wild salmon stocks from overfishing.

The Alaska Department of Fish and Game and the Prince William Sound hatchery operators pioneered the use of half-length coded wire tags for large-scale pink salmon stock identification in the mid-1980's. Coded wire tag technology was a vast improvement over no information, but its shortcomings are increasingly obvious. With coded wire tags, the time between when the fish emerge and when they go to sea limits the number of marks that can be applied. At best, only 1 in 600 Prince William Sound hatchery pink salmon can be marked with a coded wire tag. Tagged fish are then distinguished by an external fin-clip mark. Potential inaccuracies in the fraction marked have resulted in lingering doubts about the estimates on several occasions. In Prince William Sound, each decoded tag generally represents 6,000 or more untagged salmon in the harvest (1 in 600 are tagged and 10 percent of the catch is examined, $6,000 = 600/10\%$). If that one marked fish is missed by an inattentive sampler, the estimates are biased. Very recently, we have acquired new information that suggests the coded wire tagged salmon may have a slightly higher level of straying.

With new developments in fish marking, an entire hatchery release can be given a distinct mark at less cost than applying coded wire tags. Marks can be produced by controlled heat shocks to the fish in an early stage of development. This produces distinct microscopic marks on a bony structure, the otolith, of the fish.

This plan calls for developing this otolith marking technique in Prince William Sound over a period of four years, while still maintaining continuity with the existing coded wire tag program. At the end of the four years we expect the funding of the project to be converted to a cost-recovery mechanism.

If funded, this project will result in otolith marking the entire Prince William Sound hatchery production beginning with the 1994 brood year (FY95). The cost of modifying the hatcheries is expected to be approximately \$300,000. The operational costs of applying the marks are

expected to be borne by the hatchery operators beginning in 1994. Associated with the mark application are costs of approximately \$10,000 for quality control and laboratory processing of juvenile marked salmon. These otolith-marked fish will be released beginning in 1995 and will return in 1996. This project will sample the 1996 and 1997 (FY97 and FY98) fisheries for marks at a cost of approximately \$400,000 per year, including statistical analysis and reporting. In 1996 and 1997, a coded wire tag sampling program will also be in place for very little additional cost, with 1997 being the final year of coded wire tag returns. This proposal also covers limited coded wire tag processing, at a cost of \$30,000 in 1996 and 1997, to maintain continuity with the existing program. The cost of decoding the otolith marks is expected to be approximately \$100,000 per year, for the first two years. We expect to receive information in the first two years that will result in a notably less expensive program beginning in 1998. Because decoding the otoliths is a complex process requiring new equipment, people, and skills, it remains to be seen what the actual cost of the otolith program will be to exceed the accuracy and precision of the coded wire tag estimates. However, we expect a savings in the order of approximately \$50,000 per year, beginning in 1998 (FY99). A time-diagram of the entire project is provided in Appendix Table 1.

The cost of this fishery sampling program was based on the need to sample fish deliveries at up to ten locations, including Cordova, Kodiak, Kenai, Anchorage, Whittier, Seward, and floating processors -- noting that up to 15 tenders may need to be sampled to fully represent a particular fishery. The cost of sampling also reflects the need to inventory, freeze, and store all sampled fish heads containing otoliths, pre-process the otoliths before transportation to the Department's Otolith Laboratory in Juneau, and the cost of biometric analysis. The cost of decoding is based on the need to decode 160 otoliths from up to 80 fisheries at an assumed cost of \$8 per otolith. Approximately \$10,000 is requested beginning in 1995 to sample juvenile fish prior to release, examine their otoliths, and catalog the mark in the Otolith Laboratory in Juneau. This request does not cover the operational costs of the hatchery operators, which will begin in 1994.

The costs we have described here presume a functional otolith processing laboratory. We estimated the equipment needs for such a lab are approximately \$60,000, although this cost does not appear in Appendix Table 1.

This project is expected to provide inseason estimates of the hatchery contribution to important fisheries within one week of the actual fishery. The hatchery contribution to the entire common property catch is expected to be estimated to within 1 or 2 percent of the actual value. Estimates for individual periods or areas will have lower expected precision, but almost all estimates are expected to be within about 8 percent of the value obtained by examining all otoliths in the harvest. Separate estimates of the contribution of each hatchery to important fisheries will be provided, as will estimates of hatchery survival. However, if this project is funded, estimates will be provided only through the 1997 fishing season. Beginning in 1998, this vital management activity lacks a stable funding basis.

INTRODUCTION

Prince William Sound wild runs of pink salmon are at risk of overharvest. Throughout the 1980's the number of hatchery fish increased until in most years the size of the hatchery runs is far greater than the wild runs. Before the modern hatcheries, when managers observe a large abundance of fish returning to the Sound, they allowed liberal fishing. Now, with the hatcheries in place, if in a given year, the majority of the salmon are actually from hatcheries and there are few wild fish returning, then liberal fishing will lead to over-harvest of wild runs. Alternatively, if managers don't allow liberal fishing, and hatchery fish are wasted, the industry will suffer, and managers will be pressured into more liberal fishing in a future year when the wild runs are weak. The fishery managers are in an untenable position. If hatchery pink salmon are to have any hope of coexisting with wild pink salmon in Prince William Sound, and if managers are to be given a doable assignment, then managers must be given new tools to use on this increasingly complex fishery. Specifically, managers must be able to estimate the strengths of the wild and hatchery runs prior to making fishing decisions.

Previously, coded wire tags were used to generate this kind of information (Peltz and Miller 1990). Because of the enormous scale of the Prince William Sound pink salmon hatcheries, at best only about 1 in 600 hatchery fish can be marked with coded wire tags. Recently, using X-ray photographs of tag placement in returning adult salmon, we obtained new evidence that coded wire tags may be interfering with pink salmon homing.

In the Fall of 1993, the Commercial Fisheries Management and Development Division of the Alaska Department of Fish and Game held a series of meetings to plan for mass marking of hatchery pink salmon in Prince William Sound. We wanted to identify what we know and don't know about hatchery stock identification systems. Our first goal was to design a more accurate and less costly system to estimate the aggregate hatchery fraction of the pink salmon entering the Sound before fishing occurs. Our second goal was to have a means to create accurate and precise hatchery-specific estimates at the end of the season. We were looking for a system with two essential features: 1) all of the hatchery fish must possess a mark that would not harm the fish or alter its behavior, and 2) the system needs to be no more expensive than previous coded wire tagging studies.

After examining the state-of-the-art, we concluded that otolith mass marking is the preferred alternative for many reasons. The otoliths are a set of small bones in the salmon's head. Microscopic marks can be placed on the otoliths by raising and lowering the temperature of the water the salmon live in. This technique has been well researched in the State of Washington (Volk et al. 1990), at Cornell University (Brothers 1985, 1990), and in Sweden (Mosegaard et al. 1987). More recently, otolith marking was shown to be workable on a production basis in Alaskan pink salmon. This work was done at the Gastineau Hatchery, operated by Douglas Island Pink and Chum, Inc. (DIPAC) in Southeast Alaska (Munk et al. 1993). In addition, ADF&G's Snettisham Hatchery has been thermally marking sockeye salmon since 1988.

To make a mass-marking system work in Prince William Sound, a large number of complex, expensive actions need to be fully coordinated. Hatchery and fishery managers will not be given partial credit for this project. Every piece of the project must work. If all of the hatchery fish were marked, but the resources to decode the marks aren't available when the fish to return, the entire project will be of no benefit. This may seem obvious -- but many large and expensive stock-identification studies failed because one or more essential pieces were left unfunded or were not given proper attention at the critical moment. To catalogue exactly what needs to be done to reach our goals in Prince William Sound, we reviewed what we had learned first-hand with coded wire tagging of pink salmon in Prince William Sound, we looked at the scientific literature on statistical sampling and otolith marking, and then we reviewed what new information we had here in Alaska from the otolith marking of hatchery pink salmon at the DIPAC hatchery near Juneau. From there, we formed three committees to examine various aspects of the overall task. The committees examined the topics of 1) mark application, 2) mark decoding and data posting, and 3) estimators and sampling strategies. Summaries of the meetings of these committees follow.

MARK APPLICATION

Physical Changes to the Hatchery

As previously mentioned, otolith marking on a production scale was pioneered in pink salmon in Alaska at the Gastineau Hatchery, operated by DIPAC in Juneau. Their thermal marking system has been touted as the working standard, not just because it is one of the few working systems around, but because it works well. Yet, it is not capable of *simultaneously* marking 100 percent of the hatchery's juvenile pink and chum salmon (approximately 120 million), and there are additional technical problems with the degassing system. The Gastineau Hatchery operators have worked around the limitations to effect quality thermal marks, and their experience will make marking pink salmon fry much easier in Prince William Sound.

The Prince William Sound Aquaculture Corporation (PWSAC) has done some feasibility analysis for their Prince William Sound hatcheries. Their engineering firm, SSOE - Seattle, ran a concept cost estimate for Cannery Creek Hatchery using the basic design employed at Gastineau Hatchery. Capital construction and design costs were estimated at \$41,000 in April 1992. Inflation would increase that, so today's prices would be roughly \$50,000. PWSAC operates two other pink salmon hatcheries in Prince William Sound, and a fourth pink salmon hatchery is operated by the Valdez Fisheries Development Corporation (VFDA). Extrapolating for the size of the other facilities provides an estimate of \$300,000 for all four pink salmon-producing facilities in Prince William Sound. Annual operating costs were estimated to be \$12,000 per facility, though actual operational costs won't be known until the system is in use.

There are general similarities, but many distinct differences in physical plant design between the hatcheries in Prince William Sound. In the Sound, all facilities use large amounts of cold water, so substantial heating systems will be required. In general, the hatcheries can be expected to heat only 25 - 35 percent of the incubation process water at one time at any given facility.

Gas Saturation

Without degassing of rearing water, fish develop a condition called gas bubble disease. Generally, degassing is performed on all water coming into the hatchery. If the water is to be heat treated, it will require a second degassing. If part of the water is to be (super)heated and added to ambient water to achieve volume, then not only does it require degassing but rather *substantial* degassing, as mixing it with ambient water will again raise the overall saturation level. The "at-stack" temperature differential (TD) is generally from 3-4 degrees centigrade. An ability to have an "at-stack" of higher than 4 degrees centigrade may be required in future marking situations. Engineering to allow for slightly increased at-stack TD's and much greater degassing ability will keep the system flexible. The temperature change should be relatively rapid -- hot-to-cold, cold-to-hot within one-half hour. Hatchery operators have achieved this change in one-half hour or less at Gastineau Hatchery.

Gas saturation is usually not a problem for salmon embryos prior to hatching. Salmon eggs maintain a positive internal pressure which allows them to tolerate total dissolved gases (TDG) up to 110 - 116 percent. It would be uncommon to have TDGs of greater than 110 percent in incubation-process water, but it may be possible to drive TDGs this high through aggressive heating. In general, TDGs will probably not be a problem in the thermal mark application process involving eyed eggs. Testing TDGs should be required during the heating process to rule out the possibilities.

TDGs in excess of 100 percent are a concern once hatching occurs, particularly if the nitrogen component is above 100 percent. Heating water almost guarantees gas supersaturation and degassing must occur *after* final mixing of treated (superheated) water and ambient cold water. The safest approach is to treat water at use points (i.e. water flowing into incubator row head troughs). We have found that oxygen contactors are the most efficient mechanism for stripping nitrogen and contactors require much less space than screen decks. Realistically, this is probably the only feasible approach that does not involve major hatchery water supply redesign but equipment and set-up costs will add considerable expense to the water treatment process.

Mark Control

We recommend assigning a permanent mark to each hatchery that will be reused each year. A unique hatchery mark will bring consistency in both application and recovery. The familiarity is an important benefit in the mark-recovery stage. This facility mark is sometimes called the *basemark* in thermal marking. *This basemark must meet certain marking criteria, which permit rapid visual identification in the lab.* Requests for marks more specific than the hatchery identifier (e.g., separation of stocks within a hatchery, remote release, culture strategies, etc.) will be handled as needed, and will probably take the form of assigning thermally induced *accessory marks*. An accessory mark may or may not adhere to the minimum set of marking criteria imposed upon basemarks, and is *always* in addition to the basemark. If marking demand -- in terms of number of facilities -- is low, then additional requests for discrete marks by a facility may be met by assigning more than one basemark per facility.

Concerns of regional distinction between basemarks may be handled in the future by one or more of three approaches: 1) we won't assign marks with regional distinctions in mind (i.e., all Prince William Sound marks may be discrete within Prince William Sound only, but may overlap with thermal marks in Southeast Alaska); 2) we assign regionally overlapping marks and hope that secondary growth characters provide final separation; or 3) we give regional distinctions by incorporating accessory marks into the basemark. Keep in mind that once we begin to make regionally distinct marks, the mark codes will become more complex and costly in both application and recovery.

We recommend the Department create a mark committee for each marking project. We further recommend this committee be comprised of the regional fishery manager (or assistant), the hatchery manager (or the hatchery's "thermal mark coordinator"), and a designated individual from the Otolith Laboratory. The fishery and hatchery manager will identify where and to what degree separation of the stocks are needed. The hatchery manager will additionally contribute the specifics (capabilities, limitations, idiosyncracies) of their marking system. Appropriate thermal marks will be developed, in light of this and other pertinent inter- and intra-regional information, and submitted by the Lab's mark assignment coordinator to the committee members for approval.

Specific Mark Assignment

A committee met on November 5, 1991, in Cordova to discuss different mark options for all of the hatcheries in Prince William Sound. Out of that meeting came a consensus on marks for the first year. This marking scheme could be modified at any time, but currently we endorse the 1991 recommendations. Table 1 contains a summary of these recommendations.

Table 1. Proposed basemarks for Prince William Sound pink salmon hatcheries. The thermal schedule describes the temperature regime. The letter "H" refers to the Hot water event, and "C" refers to the Cold water event; the difference between the two temperature levels being 3.5 degrees Centigrade. The number directly before the thermal level is the number of rearing-hours at that level. Numbers in parentheses before an "X" denote the number of repetitions.

<u>Facility</u>	<u>Thermal Schedule</u>	<u>Banding Pattern</u>
Cannery Cr.	(3X)36H:36C,(1X)72H:36C,(3X)36H:36C	III III
AFK	(5X)36H:36C	IIII
WHN	(4X)36H:36C,(1X)72H:36C,(2X)36H:36C	III III
VFDA	(7X)48H:24C	IIIII

MARK DECODING AND DATA POSTING

The expertise and equipment to prepare and decode otoliths exists at the Otolith Laboratory in Juneau. After the otoliths are extracted from the fish, they are fixed to a glass slide with thermoplastic cement. A grinding wheel is then used to remove material from one side of the otolith to expose the internal structures. The depth of grinding is monitored by repeated viewing under a dissecting microscope. After the internal bands are exposed, the thermal mark is decoded under a compound microscope. Currently, approximately 250 otoliths can be processed and decoded by a single, experienced technician within a working day, using these techniques, although some technicians are capable of processing 400 per day. In 1993, the Otolith Laboratory processed 2,300 pink salmon otoliths. These otoliths were recovered from the commercial fishery to detect the presence of pink salmon returning to DIPAC's Gastineau Hatchery. The data obtained from these samples allowed an actual stock composition estimate in the Hawk Inlet fishery near Juneau.

Based on the conclusions of the Estimators and Sampling Strategy Committee, presented below, approximately 13,000 otoliths will initially need to be decoded from the fishery to estimate the hatchery fraction in Prince William Sound. Additionally, training sets of otoliths, from juvenile salmon will need to be collected and processed prior to release. The unit cost, including otolith removal, slide mounting, otolith cleaning, decoding, quality control, and data entry and reporting, is expected to be \$8 per otolith.

The initial equipment cost for the Otolith Laboratory *does not appear in this plan* and are assumed to be part of a statewide laboratory that will be fully operational in the future. However, the cost of equipment for Prince William Sound needs in the laboratory was estimated to be approximately \$60,000. Three otolith processing stations (\$19,000 each) will be needed to handle the peak workload resulting from the Prince William Sound fishery. Each work station will be equipped with a grinding wheel (\$2,500), dissecting microscope with fiber optic lamp (\$5,000), compound microscope (\$5,000), and image analysis system (\$6,500). In addition, single microcomputer workstation equipped with a bar-code reader (\$3,000) will be needed for data entry and data management.

The committee looked at several arrangements for the location of processing, the flow of otoliths and data, and the appropriate balance between centralized statewide functions and local control. We recommend a centralized otolith decoding laboratory for statewide processing, control of which marks are available, and database management. This option has several advantages over field-level or area office-level decoding of otoliths. A centralized facility will ensure (1) standardization of otolith thermal marking techniques, (2) lower staff turnover and reduced training costs, and (3) more efficient use of staff time due to the sporadic nature of the workload at local sites. Pre-processing involves removal of the otoliths from the head and placement in sample trays or mounting on glass slides. Local pre-processing will substantially reduce shipping costs. In the future, local decoding may be feasible for specific applications to provide, if required, more timely inseason data to fishery managers. In these cases, supervision, training, quality control, and code validation will be provided by a centralized laboratory. This will ensure consistency of decoding results.

Development of an otolith thermal marking program in Prince William Sound will initially involve application of one basemark at each of the four pink salmon hatcheries in the Sound. A single basemark for each hatchery in Prince William Sound will allow estimation of survival rate by hatchery. However, hatchery operators in Prince William Sound may also need to estimate survival rate for three treatment groups within each hatchery. In this case, a treatment-group code composed of three thermal rings will be applied in addition to the hatchery-specific basemark to distinguish among treatment groups.

Quality Control

Quality control during mark application is an important part of the otolith thermal marking program. This issue overlaps the topic of mark application and mark decoding, but it is vital to the ability to resolve confusing or ambiguous marks at the time of decoding.

The placement of the basemark on the otolith is critical. Thermal marking takes place during two relatively narrow windows: between the eyed-egg stage and hatch, and hatch and emergence. The best code quality for the basemark, with consideration of possible fish-cultural constraints, is achieved during the eyed-egg-to-hatch window. In Prince William Sound the eyed-egg-to-hatch window occurs between October and December with an average length of 35 days. Approximately 22 days will be required to apply the basemark discussed above. In Prince William Sound hatcheries, this window occurs between December and April with an average length of 150 days. The cost of heating water in the hatch-to-emergence window will be greater than before hatch due to greater water demand during this stage.

A *lot* will be defined as group of eggs taken on a single day. The basemark will be applied by lot or groups of lots when the embryos are at the appropriate stage of development. Each incubating appliance will be sampled to ensure the mark was correctly applied. An appropriate sampling plan (Thompson 1992) will be determined for each hatchery depending on the layout of the incubators, water heating system, and number of egg lots. We expect the developmental stage and, thus, basemark placement will differ among lots within the hatchery. We feel it is essential that temperature recorders be installed at various points in the incubation system during mark application to document temperature changes.

Quality control samples must be sent to the otolith decoding laboratory for processing and archival. These samples will be used to create what has come to be called the *voucher specimens* or *voucher sample*. These vouchers confirm and fully characterize the thermal mark pattern and are necessary to train the technicians who will detect the marks when the fish return as adults. The annual quality-control program for Prince William Sound hatcheries is estimated to cost \$10,000. Approximately \$10,000 will be required for two dissecting microscopes needed to extract otoliths from yolk-sac fry. This expense should be provided for in the initial cost of hatchery modification. The annual operating cost will include air charter to collect samples at the four hatcheries in Prince William Sound, as well as otolith processing and data management costs at the decoding laboratory.

An important problem in the otolith thermal mark application and decoding program is the proportion of adult returns classified as *unreadable*. In this case, an unreadable specimen is one that the reader cannot confidently classify as marked or unmarked. If unreadable otoliths comprise a large proportion of the adult marked population, an unacceptable bias may result in the population estimate, requiring complex statistical methods to come into play to adjust for the bias which will greatly reduce the precision. The proportion classified as unreadable will mostly depend upon the quality of mark application, but the character of natural banding patterns

in unmarked (wild) fish and the experience of the reader will also affect this proportion. The proportion of unreadable otoliths must be estimated from blind tests conducted with known marked fish that have been coded wire tagged. This study should be an essential element of the transition between coded wire tagging and otolith marking in Prince William Sound.

ESTIMATORS AND SAMPLING STRATEGIES

This committee met in Juneau on September 17, 1993. The goals of the meeting were (1) to develop an acceptable sampling strategy for estimating hatchery and wild pink salmon contributions to the various fishery catches of Prince William Sound, (2) to estimate the number of otoliths that would need to be decoded, and (3) to estimate the cost of sampling and decoding. An acceptable sampling strategy was one which, when combined with suitable estimators, would provide unbiased contribution estimates that are as precise or more precise than those generated by the present coded wire tag program.

The coded wire tag program has provided usable estimates since its initiation in 1987. This work provided great improvements in the estimation of fisheries contributions -- although we are now finding that the program does have some shortcomings. Nearly all of the problems with coded wire tags revolve around the fact that not all hatchery fish are tagged. In the proposed thermal marking program, these problems are side-stepped since all fish in a treatment group will possess a mark. This property, coupled with the knowledge gained through the coded wire tag work, has the potential to make a thermal marking program an effective fisheries management tool, one that is capable of improving the accuracy and precision of the contribution estimates at a similar or lower cost.

Sampling Strategy

We began our discussion of the sampling strategy by asking how big the sampling program needs to be. From earlier coded wire tag studies, we know different processors end up with different ratios of wild and hatchery fish, even from the same fishing district. These differences are due to assorted locations of tenders that buy fish from individual boats out on the fishing grounds. Consequently, to generate unbiased estimates in either a coded wire tag program or otolith program, samplers must be present at all of the processors where significant numbers of salmon captured in Prince William Sound are delivered. In the past, samplers needed to be stationed in Cordova, Valdez, Whittier, Seward, Homer, Kodiak, Kenai, Anchorage, and aboard floating processors. The number of locations, distance between them, and the likelihood that fish will be delivered to all of them at the same time determine the size of the sampling program. After

reviewing the coded wire tag sampling needs, we found that the size of the sampling program for otoliths will need to be quite similar: the estimated cost of the otolith field collection program, biometric support, and final report is \$400,000.

Sampling Mechanics

Efforts will be made to sample as many tenders as possible from each processor. One technician will be required to sample a tender. Approximately 100 fish will be selected from each tender as the fish are unloaded at the processor using a strict protocol that will closely approximate random selection. The heads will be removed and marked with a numbered cinch strap for inventory tracking. The heads will be separated, by tender, and sent to the Alaska Department of Fish and Game office in Cordova. Information on the total number of fish aboard the tender and the district of catch will also be collected at the time of delivery. The otoliths will be removed from the heads, catalogued, and stored in Cordova.

A composite otolith pool will be formed for each fishery using the otoliths collected from the individual tenders in conjunction with the catch data collected from the tenders and processors. The proportion of the total catch delivered to each processor will be estimated for the fishery in question. This proportion will be used to establish the number of otoliths which will represent the processor in the composite pool. The number of fish landed for each tender within a processor unit will be used to determine the number of otoliths to be used from each tender. All selections will be done in a random manner after the number of otoliths to select has been established. The remaining otoliths will be saved in case further analysis is desired.

The composite otolith pool will be sent to Juneau for analysis. Initially, 50 otoliths will be randomly selected from the composite pool, read, and classified as either wild or hatchery (marks will be further classified to hatchery of origin). This will almost always provide the fishery manager with an initial estimate of the fishery contributions to within 15 percent of the true contribution for the case where the estimate has the largest variance: when wild and hatchery are in equal proportions in the mixture. The estimates of hatchery contribution will almost always be more precise than our planning assumptions. In many cases, an estimate of this precision will be sufficient for making fishery management decisions. For those situations where a more precise estimate is required, it would be quite easy to call the Otolith Laboratory and request additional otoliths be read.

The fishery contribution estimates will be examined post-season and decisions will be made as to how to allocate any remaining otolith reading resources. Efforts will be made to improve the precision about critical estimates as well as the possible evaluation of other special harvests.

Sample Size

We estimated the number of otoliths required for a season by assuming that approximately 80 contribution estimates would be made (eight fishing districts by 10 weeks). Obviously, not all districts will be fished each week, but some districts will have multiple openings during a given week. We then estimated that a sample of 160 otoliths per contribution estimate would provide adequate precision for most estimates.

The gain in precision beyond that obtained by a sample size of 160 is extremely expensive. The precision in the estimate of the fraction marked will be lowest when there is an even mix of wild and hatchery fish. A sample size of 160 would provide 95 percent confidence that the estimate will be ± 7.7 percent for a single fishery, with such an even mix. A sample size of 384 would be required for a precision of ± 5.0 percent at 95 percent confidence, for a single fishery estimate. The gain of 2.7 percent in precision would cost approximately \$1,800 for that single fishery. At the level of the entire program, this cost would exceed \$100 thousand, but the gain in precision would be minuscule.

The overall estimate for the number of otoliths to be decoded in a season was thus approximately 13,000. Pete Hagen, the director of the Otolith Laboratory, estimated the cost of decoding an otolith at \$8 per fish. The estimated cost of decoding all of the otoliths was approximately \$104,000. When combined with the estimated cost of sampling the fishery, the total cost of adult mark recovery is approximately \$500,000.

There was some discussion on the statistical theory of estimation. Hal Geiger is proposing a Bayesian approach to estimating wild and hatchery contributions. This method has appealing statistical properties, the most attractive of which would allow us to "peek" at the results of the first 50 otoliths and then decide whether we need to process more. This method of minimizing sampling to obtain a desired level of precision is advantageous when each sample has a high cost. A second appealing property is the ability to incorporate prior knowledge into the estimate. Fishery managers and researchers who have spent years watching particular fisheries, develop a "feeling" for what the true contributions for an opening will be. Likewise, information from the last opening or a test fishery is often used as a criteria for deciding whether to open again. This methodology is able to take into account this valuable knowledge. Finally, the measure of uncertainty about our estimates is in the form of a probability density, and the resulting confidence statements (credibility intervals) are more in line with the colloquial understanding of probability. We left the meeting with the agreement to further evaluate the Bayesian approach.

In summary, we believe (1) we have a workable means of sampling the fishery and this sample will be representative of the catch, (2) the number of otoliths to be read from the fishery samples is reasonable and should be completed in a timely manner, and (3) the statistical methodology while not totally agreed upon at this time shows great promise and will most likely be accepted. Our estimated for the sampling, otolith reading, and reporting is \$500,000.

LITERATURE CITED

- Brothers, E.B. 1990. Otolith marking. Fish Marking Techniques. American Fisheries Society Symposium 7:183-202.
- Mosegaard, H, N.G. Steffner, and B. Ragnarsson. 1987. Manipulation of otolith microstructure as a means of mass-marking salmonid yolk sac fry. [In] Proc. 5th Cong. Europ. Ichthyol., Stockholm. 1985. pp. 213-220.
- Munk, K.M, W.W. Smoker, D.R. Beard, and R.W. Mattson. 1993. A hatchery water-heating system and its application to 100 percent thermal marking of incubating salmon. Progressive Fish-Culturist 55:284-288.
- Peltz, L. and J. Miller. 1990. Performance of half-length coded wire tags in a pink salmon hatchery marking program. Fish Marking Techniques. American Fisheries Society Symposium 7:244-252.
- Thompson, S.K. 1992. Sampling. Wiley-Interscience. New York. 344 p.
- Volk, E., S.L.Schroder, and K.L. Fresh. 1990. Inducement of unique banding patterns as a practical means to mass-mark juvenile Pacific salmon. Fish Marking Techniques. American Fisheries Society Symposium 7:203-215.

APPENDIX

Appendix Table 1. Schedule of stock identification activities and estimated costs of otolith marking for Prince William Sound pink salmon. Costs associated with ongoing coded wire tag studies are not included. Operational costs of marking are assumed to be borne by the hatchery operators.

Schedule of Stock ID Activities

Calendar Year	1993	1994	1995	1996	1997	1998	
Fiscal Year	FY94	FY95	FY96	FY97	FY98	FY99	...
Coded Wire Tag							
Apply Tags	Yes ¹	Yes	Yes	Yes	No	No	...
Sample Fishery	Yes	Yes	Yes	Yes ²	Yes ²	No	...
Otolith Marks							
Install Heaters	No	Yes	No	No	No	No	...
Heat Shock Juveniles	No	Yes	Yes	Yes	Yes	Yes	...
Sample Fishery and Decode	No	No	No	Yes ²	Yes ²	Yes	...
Juvenile Knowns to Lab.	No	Yes	Yes	Yes	Yes	Yes	...

¹These activities are not part of the otolith development process, and are not funded as part of this package.

²A developmental otolith program and a limited coded wire tag program will be in place in these years.

Appendix Table 1. (Continued)

**Cost of Hatchery Modification, Sampling and Mark Decoding,
in Units of \$1000**

Not included are hatchery operational costs.

Calendar Year	1993	1994	1995	1996	1997
Fiscal Year	FY94	FY95	FY96	FY97	FY98
Coded Wire Tag					
Decode Tags	\$0	\$0	\$0	\$30	\$30
Otolith Marks					
Install Heaters	\$0	\$200	\$0	\$0	\$0
Sample Fishery and Decode	\$0	\$0	\$0	\$500	\$500
Juvenile Knowns to Lab.	\$0	\$10	\$10	\$10	\$10

Appendix Table 2. Committee members

Mark Application:	Mark Decoding and Data Posting	Estimators and Sampling Strategy:
Tim McDaniel (Chair) Jeff Olsen (from PWSAC) Kris Munk	Mark Willette (Chair) Pete Hagen Karen Crandall Kris Munk	Brian Bue (Chair) Pete Hagen Sam Sharr David Evans Hal Geiger